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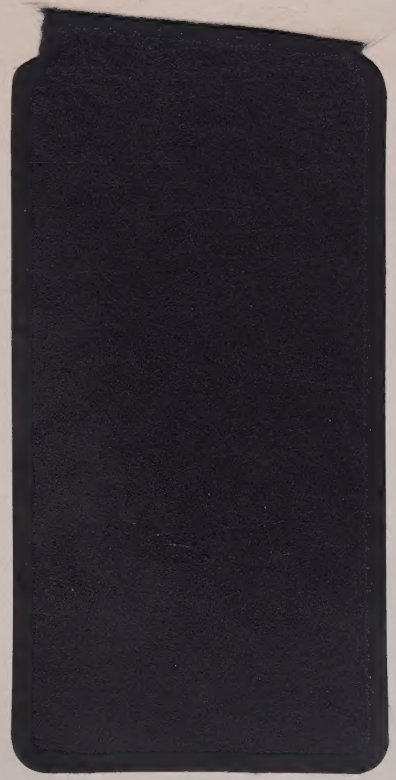
INSTRUCTION MANUAL

MODEL 502

MILLIOHMMETER

KEITHLEY INSTRUMENTS



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MILLIOHMMETER

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WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof, except tubes, transistors, fuses, and batteries, which, within a year after shipment to the original buyer, proves defective on examination.

DAMAGE IN SHIPMENT

Be sure to include the instrument model number and serial number in all communications.

If the instrument is damaged when received, or fails to operate properly, a claim should be filed with the carrier. Upon receipt of the claim agent's report, we will inform you regarding repair or replacement.

REPAIRS

When returning an instrument for repair or recalibration, it should be securely packed against shipping damage and sent to the factory, freight prepaid. A brief letter describing the difficulty should accompany the instrument.

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SECTION I - INTRODUCTION

The Keithley Model 502 is a battery operated, portable milliohmmeter for measuring resistances from 0.00003 to 1000 ohms. The instrument employs an AC testing method, eliminating zero drift and permitting resistance readings in the presence of DC currents. The reading is presented on a linear scale panel meter.

Typical applications of the instrument include measurement of contact resistance, conductivity of semi-conductor samples, fuse and squib testing, and electrolyte conductivity.

Maximum power dissipation in the sample is 2 microwatts, permitting the measurement of detonator fuses without danger of detonation. In the measurement of contact resistance, the model 502 may be considered a "dry circuit" tester. However, the instrument may be used in the presence of DC biasing currents to measure the change in resistance caused by these currents.

SECTION II - SPECIFICATIONS

RANGES. The current used on each range (one half the peak current), the input voltage drop, and the sample dissipation for a full-scale reading on each range are:

Range Ohms	Average Applied Current, Milliamperes	Voltage Drop, Microvolts	Maximum Dissipation Across Sample, Microwatts
0.001	10	10	0.2
0.003	10	30	0.6
0.01	10	100	2.0
0.03	3.33	100	0.66
0.1	1	100	0.2
0.3	0.33	100	0.066
1	0.1	100	0.02
3	0.2	600	0.24
10	0.06	600	0.072
30	0.02	600	0.024
100	0.006	600	0.0072
300	0.002	600	0.0024
1000	0.0006	600	0.00072

ACCURACY is three percent of full scale on all ranges except the 0.001 range, where it is five percent of full scale. Less than two percent error is added in measuring samples with a series inductive impedance less than 20% of the resistance, or with a parallel capacitive admittance less than 6% of the conductance, at 100 cps.

SAFETY AND RELIABILITY. Maximum power dissipation across the sample with improper range setting is three milliwatts. Maximum dissipation caused by failure of a component in the current source is double the power tabulated above. Maximum dissipation caused by combined component failure and improper range setting is six milliwatts.

WARM-UP TIME is 30 seconds maximum.

BATTERY TEST shows that a battery has failed when meter reads below half scale. Batteries are:

CIRCUIT NO.	VOLTAGE	BATTERY TYPE	MINIMUM HOURS LIFE
B1	1.34	Mallory RM 12R -	360
B2	1.34	Mallory RM 401R	Shelf
B3	1.34	Mallory RM 42R -	460
B4	22.5	Eveready 412 -	800
B5	30.0	Eveready 413	Shelf
B6	1.34	Mallory RM 401R	8000

TUBE COMPLEMENT: 4-6419, 1-6418

TRANSISTOR COMPLEMENT: 4-2N1381

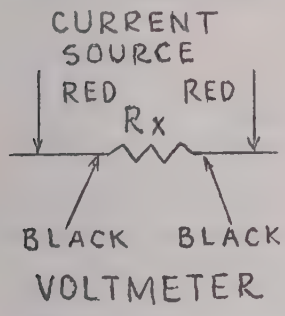
ACCESSORIES FURNISHED: One pair each of current and voltage leads.

SECTION III - OPERATION

A. CONNECTIONS

(1) LOW resistances (less than 3 ohms).

Connect the current supply leads (red) to the sample at any point which assures current flow through the entire sample. This connection may include the leads on the sample.



Connect the voltmeter leads (black) across only that part of the sample which is to be measured, as shown in the diagram. If the terminal or test leads of the resistance being measured are included within the voltmeter clips, the reading will include the resistance of these leads.

DO NOT CONNECT THE RED CLIPS TO THE BLACK CLIPS. The clip-to-sample resistance of both voltmeter clips are added in series with the unknown, and large errors can result.

(2) HIGHER resistances (3 ohms and greater).

For ranges over 3 ohms full scale, the clip contact resistance is insignificant compared with the full scale value, so voltage and current leads may be paired and the standard two-terminal ohmmeter method employed. Of course, the four-terminal method above may be used, but the two terminal method is faster for repeated testing.

B. PROCEDURE

Turn the power ON while the READ-SHORT switch is at SHORT. The instrument will stabilize in about 15 seconds.

Connect the leads to the sample as outlined above. Then move the READ-SHORT switch to READ. Rotate the OHMS FULL SCALE switch until a suitable on-scale reading is obtained.

The READ-SHORT switch shorts the voltage input in the SHORT position. It keeps the meter pointer on scale while the test leads are being connected to an unknown. If an overload is applied to the input by inadvertently opening the READ-SHORT switch, no damage will result. However, approximately 30 seconds will be required for the amplifier to recover.

C. BATTERY TEST

Before a reading is made, it may be desirable to check overall circuit operation. This is done by rotating the range switch to BATT. - TEST and switching the READ-SHORT switch to READ. The meter should read within one division of the red line on the meter face marked BATTERY TEST. Failure of the unit to read at the red line indicates a circuit failure which, in most cases, will be battery failure. Consult SECTION V - MAINTENANCE for battery changes or troubleshooting information.

D. PRECAUTIONS

On full scale ranges of one ohm and below, the amplifier has sensitivities in the microvolt region and a pass band which includes 60 cps. Thus, a loop in the voltage leads which encloses any 60 cps magnetic field may give a meter indication. Care should be exercised to avoid such magnetic loops. Care should also be taken in shielding critical circuits to avoid 60 cps pickup from electric fields; in general, however, the electrostatic pickup is not serious at the impedance involved. One way to test for pickup is to remove the current supply leads with the voltage leads connected to the sample. If no reading appears on the meter, no pickup is present. If some reading does occur due to the presence of 60 cps magnetic field, it may be reduced to a minimum by rotating the meter for minimum pickup. In any case, the instrument reads correctly above any residual reading. For example, if the 502 reads, say, .002 ohms due to the presence of stray fields with the voltmeter leads shorted, a .003 ohm resistance being tested will still read .003 ohms. This is because the 60 cps signal is superimposed on the 100 cps square wave test signal. Thus the 60 cps signal is not rectified and the meter reads only the rectified square wave.

Because of the AC technique employed, inductive and capacitive components in the test impedance may cause some waveform distortion and erroneous readings. Series inductive impedance (at 100 cps) less than 20% of the resistance cause the reading to be less than 2% high. Shunt capacitive admittance (at 100 cps) less than 6% of the conductance cause the reading to be less than 2% low. Listed below are the limiting values of inductance and capacitance to cause 2% error at full scale on any range:

RANGE	MAX SERIES INDUCTANCE	MAX SHUNT CAPACITANCE
.001 ohms	.3 microhenries	over 1000 microfarad
.003	.9	
.01	3	
.03	9	
.1	30	
.3	90	750 microfarad
1.0	.3 millihenries	250
3.0	.9	75
10.0	3	25
30	9	7.5
100	30	2.5
300	90	.75
1000	.3 henries	.25

It is well to remember that basically, the Model 502 is measuring the voltage across the sample resistance due to current flow in the sample. So long as the sample current is generated by the Model 502, no difficulties should be encountered. However, if other currents are flowing in the sample in addition to the test current, these currents must be either small compared with the test current or essentially dc. The Model 502 will read a resistor in the milliohm region which is carrying more than 50 amperes of direct current, but even .01 amperes of alternating current whose frequency is within the pass band of the amplifier will cause a serious error.

When measuring samples across which a dc voltage greater than about .05 volts may appear, a blocking capacitor should be used in series with one current lead and another capacitor in series with one voltage lead. Use 1000 mfd at a voltage rating sufficient to handle the dc sample voltage.

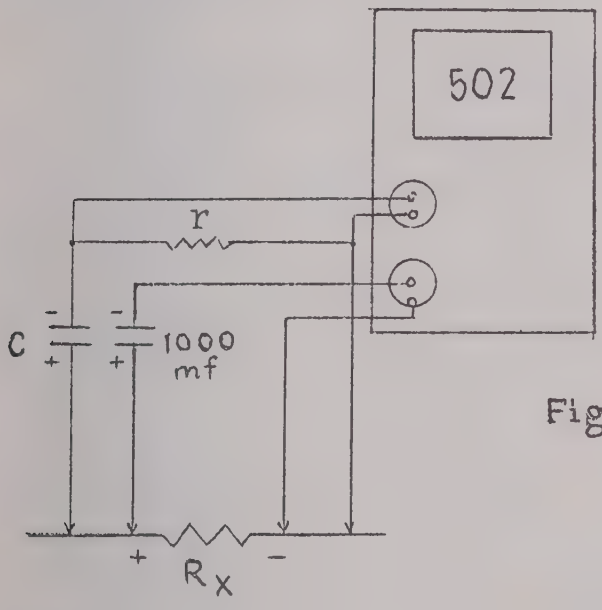


Fig. 1

The setup is shown in Fig. 1. If this arrangement is to be used on the ranges below .3 ohm, also include r as shown. This resistor is to provide a d.c. return path for the output transistor, Q4.

Values of r and C are shown below:

Range	r	C	Added error
.1	100	1000 mfd	-1%
.03	47	1000	-3%
.01	10	4000	-6%
.003	10	4000	-6%
.001	10	4000	-6%

SECTION IV - CIRCUIT DESCRIPTION

The standard method of measuring resistance assumes that test lead resistance is negligible. When measuring resistances at or below the level of lead resistance, a more sophisticated approach is required.

The four-terminal method of resistance measurement consists of supplying current from an isolated current generator to the sample, and measuring the voltage drop across the sample with an isolated voltmeter. The generator is made to supply constant current regardless of lead resistance so that no errors occur due to current lead connection. The voltmeter has large enough input resistance so that the voltage lead resistance does not cause any error. Since there is no current error and voltage error, the resistance is read correctly.

The 502 circuit consists of two parts: a 100 cps transistor squarewave generator supplies the current across the sample and the AC microvolt meter measures the voltage drop. The panel meter is calibrated directly in ohms on a linear scale. Refer to the circuit diagram, DR 12189-C.

(1) Square Wave Generator. The 100 cps square wave is generated by a transistor multivibrator consisting of Q1 and Q2. R146 is a symmetry control which is set at the factory to give a symmetrical square wave. This adjustment is necessary to insure no change in reading when the current leads are reversed. Q3 and Q4 serve as a power amplifier. Transistor Q4 acts essentially as a 100 cps switch connecting and disconnecting B1 across the sample and series resistors R132 through R142. Due to the fact that the output peak voltage is more than 95% of the mercury battery voltage, the change in square-wave amplitude with change of transistor parameters is very small. B6 supplies a small negative bias current through R151 to the output transistor to insure good cut off characteristics, at a high ambient temperature.

(2) AC Amplifier. The ac amplifier is a conventional vacuum tube voltmeter with meter current feedback. The input signal is matched to the vacuum tube input by an input transformer on the more sensitive ranges. Above 1 ohm, the input transformer is not used.

The input voltage is compared to the feedback voltage through R101 and R102 into the grid of V1. V1, V2, V3, V4, and V5 amplify the error signal. The output voltage is full-wave rectified by D1 and D2 to supply indicating meter current. The ac current through the meter and rectifiers flows in R128, R129 or R130 to supply feedback voltage to the first stage. The dividers R103 and R126 or R127 allow separate calibration of the ranges which employ transformer input and the ranges which do not.

ON BATTERY TEST, the unit is automatically placed on the 1000 ohm range. A 500 ohm resistor, R149, is connected into the test position and the external current and voltage leads are disconnected. Since battery current drain is essentially the same on all ranges, this test will indicate faulty batteries immediately by giving a reading less than normal.

SECTION V - MAINTENANCE

A. BATTERIES

Under normal conditions the only maintenance required will be the replacement of batteries. To reach the batteries, remove the four screws at the rear and slide the instrument out of the case. The batteries are all located in holders at the top of the instrument.

B1, supplying the current generator, and B3, which supplies the vacuum tube filaments, should have a useful life of about 460 hours unless the instrument is used continuously on the lowest three ranges. This may shorten the life of B1 to 360 hours. B4, which supplies plate potential to the output tube should last through about two changes of B1 and B3. B2, the bias battery, B5, the plate supply for the amplifier, and B6, the negative bias for the output transistor, should last about two years. To be certain of always having fresh batteries, a good practice would be to change all batteries whenever one of the set needs replacement.

B. TROUBLE-SHOOTING

If the circuit fails to perform properly and the batteries are found to be good, a step-by-step procedure should be followed to discover the fault.

First check the current supply wave form at the current output terminals. This should be a 100 cps square wave about 1.3 volts amplitude. Switch to the 1 ohm range so that oscilloscope loading will not affect the wave form. If the desired wave form is not present, check the generator circuit stage by stage. Q1 and Q2 are connected as a multivibrator. Q3 and Q4 are cascaded emmitter followers which develop the output current drive.

If the current supply works properly, check the voltage amplifier. First compare observed operating potentials with those given in the Voltage Diagram in this section. When operating points are all correct, the amplifier may be checked stage by stage for amplification. Note that V5 is used to supply current to the meter, and therefore has a voltage gain of only about one.

The voltage required at the junction between C115 and the meter diodes for full scale deflection is approximately 0.75 volt RMS.

The Voltage Diagram, DR 12256-C, Circuit Schematic, DR 12189-C, and parts list are included at the back of the manual.

REPLACEABLE PARTS LIST - MODEL 502

Circuit Designation	Description	Keithley Part No.
B1	Battery 1.3 volts, RM 12R	BA7
B2	Battery 1.34 volts, RM 401R	BA8
B3	Battery 1.3 volts, RM 42R	BA10
B4	Battery 22.5 volts, #412, Eveready	BA4
B5	Battery 30 volts, #413, Eveready	BA5
B6	Same as B2	
C101	Capacitor, tubular, electrolytic, 2 mfd, 50 VDCW	C39-2
C102	Capacitor, silver mica, 1000 mmf, 500 VDCW	C21-.001
C103	Capacitor, mylar, 8200 mmf, 100 VDCW	C38-.0082
C104	Capacitor, mylar, 0.1 mfd, 50 VDCW	C41-.1
C105	Same as C101	
C106	Same as C102	
C107	Capacitor, silver mica, 820 mmf, 300 VDCW	C21-820
C108	Same as C104	
C109	Same as C101	
C110	Capacitor, silver mica, 100 mmf, 500 VDCW	C21-100
C111	Same as C107	
C112	Same as C104	
C113	Same as C101	
C114	Capacitor, paper metalized, 1.0 mfd, 200 VDCW	C18-1
C115	Same as C114	
C116	Same as C104	
C117	Same as C114	
C118	Same as C114	

REPLACEABLE PARTS LIST - MODEL 502

Circuit Designation	Description	Keithley Part No.
D1	Diode, Silicon, Transistron, IN482	RF-14
D2	Same as D1	
M	Meter, 0-50 microampere, ruggedized	ME13
Q1	Transistor, type 2N1381	TG-2N1381
Q2	Same as Q1	
Q3	Same as Q1	
Q4	Same as Q1	
R101	Resistor, deposited carbon, 1M, 1%, ½W	R12-1M
R102	Same as R101	
R103	Resistor deposited carbon, 60K, 1%, ½W	R12-60K
R104	Resistor, deposited carbon, 2.2M, 1%, ½W	R12-2.2M
R105	Resistor, deposited carbon, 5M, 1%, ½W	R12-5M
R106	Resistor, composition, 100K, 10%, ½W	R1-100K
R107	Resistor, composition, 22M, 10%, ½W	R1-22M
R108	Resistor, composition, 2.2M, 10%, ½W	R1-2.2M
R109	Same as R108	
R110	Resistor, composition, 10M, 10%, ½W	R1-10M
R111	Same as R106	
R112	Same as R107	
R113	Same as R108	
R114	Same as R108	
R115	Resistor, composition, 3.9M, 10%, ½W	R1-3.9M
R116	Same as R106	
R117	Same as R107	
R118	Same as R108	
R119	Same as R108	

Circuit Designation	Description	Keithley Part No.
R120	Same as R110	
R121	Same as R108	
R122	Resistor, composition, 47K, 10%, ½W	R1-47K
R123	Resistor, deposited carbon, 5K, 1%, ½W	R12-5K
R124	Same as R123	
R125	Resistor, deposited carbon, 2.5K, 1%, ½W	R12-2.5K
R126	Potentiometer, wire wound, 3K, 10%	RP3-3K
R127	Potentiometer, wire wound, 1K, 10%	RP3-1K
R128	Resistor, deposited carbon, 100 ohms, 1%, ½W	R12-100
R129	Resistor, deposited carbon, 300 ohms, 1%, ½W	R12-300
R130	Resistor, deposited carbon, 1K ohms, 1%, ½W	R12-1K
R132	Resistor, deposited carbon, 60 ohms, 1%, ½W	R12-60
R133	Resistor, deposited carbon, 180 ohms, 1%, ½W	R12-180
R134	Resistor, deposited carbon, 600 ohms, 1%, ½W	R12-600
R135	Resistor, deposited carbon, 1.8K, 1%, ½W	R12-1.8K
R136	Resistor, deposited carbon, 6K, 1%, ½W	R12-6K
R137	Resistor, deposited carbon, 3K, 1%, ½W	R12-3K
R138	Resistor, deposited carbon, 10K, 1%, ½W	R12-10K
R139	Resistor, deposited carbon, 30K, 1%, ½W	R12-30K
R140	Resistor, deposited carbon, 100K, 1%, ½W	R12-100K
R141	Resistor, deposited carbon, 300K, 1%, ½W	R12-300K
R142	Resistor, deposited carbon, 1M, 1%, ½W	R12-1M
R143	Resistor, deposited carbon, 82 ohms, 1%, ½W	R12-82
R144	Resistor, deposited carbon, 1.5K, 1%, ½W	R12-1.5K

REPLACEABLE PARTS LIST - MODEL 502

Circuit Designation	Description	Keithley Part No.
R145	Same as R123	
R146	Potentiometer, wire wound, 10K	RP9-1
R147	Same as R123	
R148	Same as R144	
R149	Resistor, deposited carbon, 500 ohms, 1%, ½W	R12-500
R150	Same as R101	
R151	Resistor, composition, 15K, 10%, ½W	R1-15K
SW1	Switch, push-pull, DPDT	SW7
SW2	Switch, input short	SW59
SW3	Switch, range 14 position	SW57
T1	Transformer, input	TR25
V1	Vacuum tube, type 6419	EV6419
V2	Same as V1	
V3	Same as V1	
V4	Same as V1	
V5	Vacuum tube, type 6418	EV6418

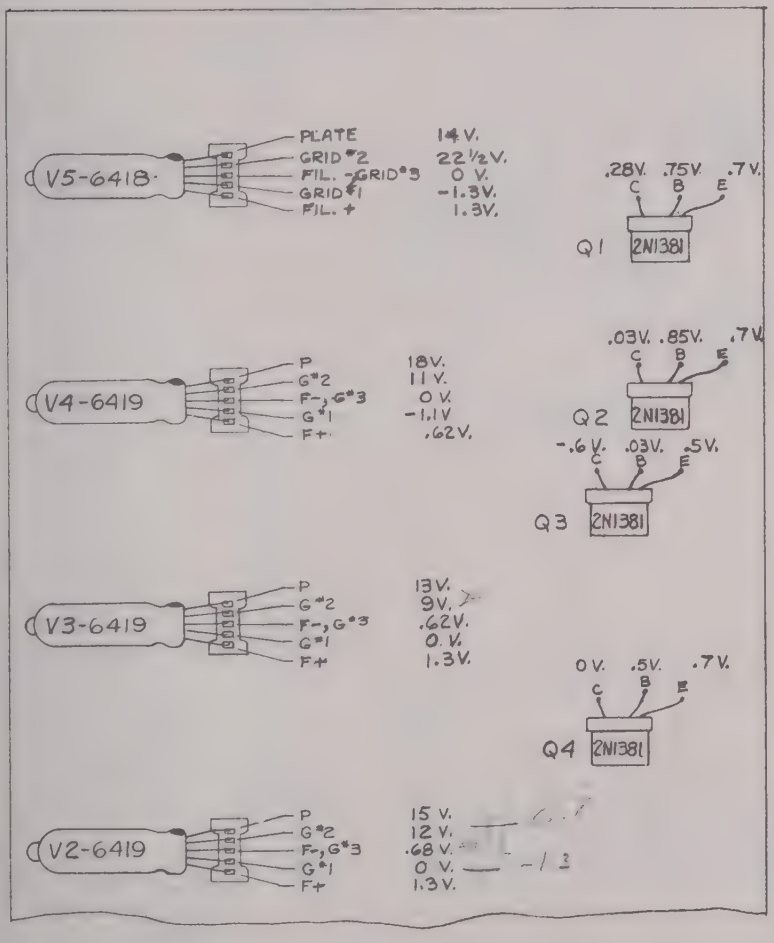
DR 12256-C

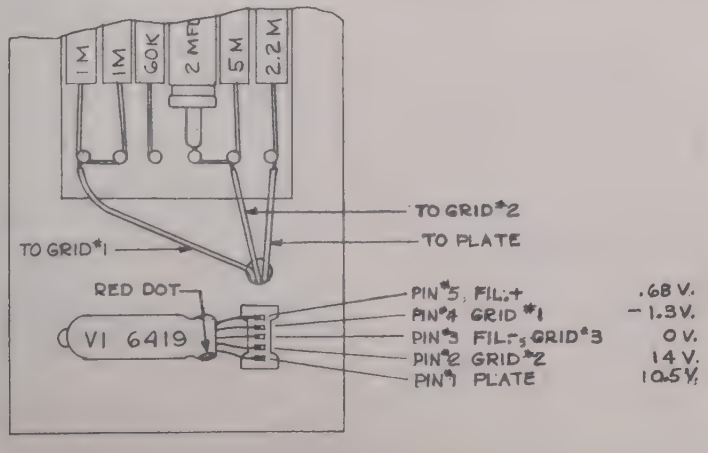
MODEL 502
VOLTAGE CHART

TUBE AND TRANSISTOR VOLTAGES ARE MEASURED FROM TUBE PIN TO CHASSIS GROUND WITH CONTROLS SET AS FOLLOWS:

RANGE SWITCH AT 'BATTERY TEST'
READ SHORT SWITCH AT 'SHORT'.

ALL READINGS ARE APPROXIMATE AND ARE TAKEN WITH AN 11 MEGOHM INPUT RESISTANCE VTVM.





C	REVISED PER CHANGE # 741	3-1-60
B	REVISED PER CHANGE 601	12-18-59
A	REVISED PER CHANGE #570	12-9-59

MODEL 502
VOLTAGE CHART

KEITHLEY INSTRUMENTS
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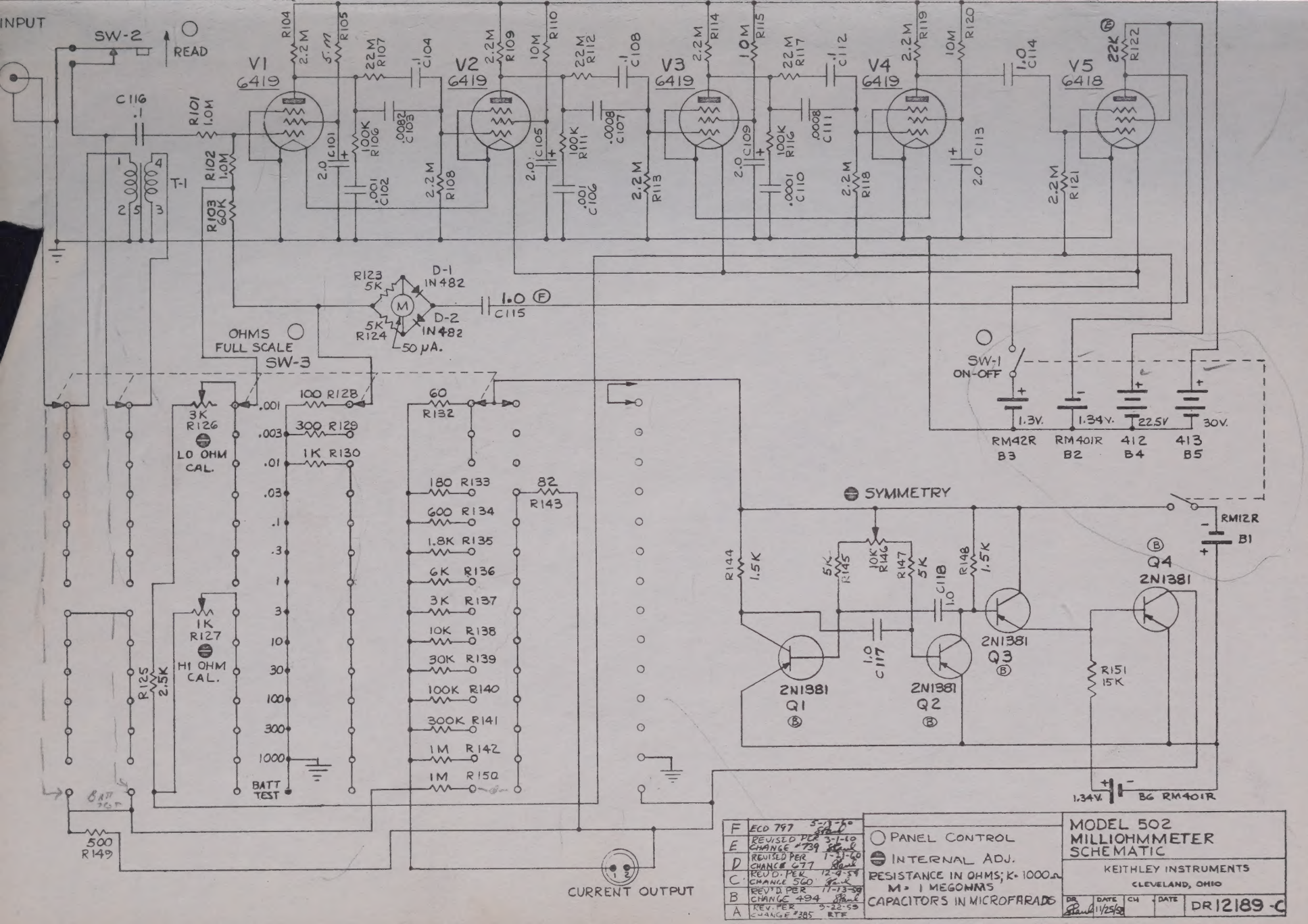
DR 12256-C



F	ECO 797	5-1-60
E	REVISED PER CHANGE #739	3-1-60
D	REVISED PER CHANGE 677	1-1-60
C	REV'D. PER CHANGE 560	12-9-59
B	REV'D PER CHANGE 494	11-13-59
A	REV. PER CHANGE #385	9-22-59

○ PANEL CONTROL
⊖ INTERNAL ADJ.
RESISTANCE IN OHMS; K = 1000Ω
M = 1 MEGOHMS
CAPACITORS IN MICROFARADS

MODEL 502
MILLIOHMMETER
SCHEMATIC

KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

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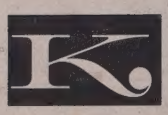
DR12189-C



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